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ERRATA

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(i) individual instead of *Individual*
(ii) Camellia instead of *Camelia*
(iii) sinensis instead of *Sinensis*

Page 3 — Right-hand column, line 1
5 rates instead of *5 rate*

TOPPING TRIALS

Page 3 — Right-hand column, line 1
flower or instead of *flower of*

Page 7 — Table 3
1. Circumference instead of *Circumferences*
10. neighbours instead of *neighbourgs*

Page 8 — Table 4
Tippings instead of *Tipings*

Page 11 — Under Introduction, line 7
characteristic instead of *characteristtic*
Left-hand column, line 2
mature instead of *nature*

Page 21 — Fig. 1 : Along vertical axis
To read Yield/Kg $\times 10^3$

Page 23 — Left-hand column, one paragraph before last
Verdun instead of *Vedun*

Page 26 — left-hand column, line 3
oxidation instead of *exidation*

Recent Research in Tobacco Cultivation

by

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RESUMÉ

Deux types de tabac, Nicotiana tabacum L. sont produits à Maurice—tabac clair séchés à l'air naturel et tabac de Virginie séché à l'air chaud. La 'Division of Agronomy' est responsable de la production des semences et de la recherche.

SUMMARY

Two types of tobacco Nicotiana tabacum L. are produced on a commercial scale in Mauritius, namely air-cured (light-coloured) and flue-cured Virginia. The Division of Agronomy is responsible for seed production and research work to support the industry.

INTRODUCTION

Air-cured (light-coloured) and flue-cured Virginia are the only two types of tobacco, *Nicotiana tabacum* L. grown on a commercial scale in Mauritius. Production is however limited to the estimated requirements of the local cigarette-manufacturer. Presently, unmanufactured tobacco is not exported, but nonetheless the crop ranks third in economic importance after sugarcane and tea. About 680 tonnes of flue-cured tobacco have been produced annually for the past 10 years, but as much as 1107 tonnes were produced in 1981.

Tobacco is cultivated for its non-edible leaves. These are harvested by priming (as they ripen), cured (dried), graded (according to colour, degree of damage or spotting length), aged and used in the manufacture of cigarettes and pipe-tobacco. Depending upon weather conditions, the seedlings remain for about 6 to 8 weeks in the nursery; Virginian varieties would grow and allow harvest of ripe leaves in the following 4 to 5 months while air-cured Amarello plants would complete their crop cycle in the next 6 to 7 months.

The Ministry of Agriculture, Fisheries and Natural Resources provides vital services to support the local tobacco industry in terms of seed production and research. Tobacco seed production is carried out solely by the Division of Agronomy and tested seeds (in terms of purity, germination and absence of disease—causing organisms) are issued free of charge through the Tobacco Board to registered tobacco growers. Such a centralised seed production service provides the guarantee to the industry of an improved stock, true to the varietal characteristics.

Results of research work and recommendations are passed on to growers through the Inspection Section of the Tobacco Board, but there is also direct contact between scientists and farmers.

Research programmes are orientated to generate information which is essential in the production of tobacco. New varieties are regularly introduced and after undergoing seed-to-seed quarantine, are assessed in terms of leaf yield, leaf quality and disease and pest-resistance. Field trials are also set-up to review cultural practices with a view to developing new techniques and at the same time reducing production costs. Field trials with flue-cured tobacco are carried out twice a year—the first season starts in January and the second season in June. Air-cured tobacco, because of its longer crop cycle, is grown in one crop and is usually sown around mid-March. This paper reviews the important agronomic aspects of tobacco research.

SELECTION OF VARIETIES

(a) Air-cured

Air-cured tobacco variety Amarello was first introduced in 1929. It underwent gradual selection and improvement and in the 1940's, it was crossed with the cigar-wrapper variety Rg. and a line showing resistance to Black shank (caused by *Phytophtora parasitica* var. nicotianae) was developed. Further selections led to the presently standard air-cured variety and this work continues in the seed production programme where plants are selected on basis of yield components and resistance to disease and pests.

With increasing demand for air-cured tobacco (from about 92 tonnes in 1978 to about 272 tonnes in 1983), new varieties have been introduced and are presently under trial. The performance of five varieties under experimentation in 1984 are presented in Table 1. For its first trial at Richelieu Experiment Station, variety Palotina from Brazil, achieved a slightly higher cured leaf yield (3.39 t/ha) than variety Amarello (3.30 t/ha).

TABLE 1

COMPARATIVE PERFORMANCE OF 5 AIR-CURED TOBACCO VARIETIES UNDER TRIAL IN 1984*

Varieties	*Cured leaf yield (t/ha)*	*Grade index (Rs/kg)*	*Gross returns ('000 Rs/ha)*	*No. of days to flowering*	*No. of marketable leaves/plant*	*Topping height (cm)*
Amarello	3.30[a]	19.48[a]	64.39[a]	90	31.7	126
Barracao	2.48[b]	18.95[a]	46.99[b]	83	26.1	118
Espada	2.41[b]	19.12[a]	45.95[b]	76	22.4	107
Irabourbon N1 ...	3.23[a]	19.42[a]	61.39[a]	90	30.6	124
Palotina	3.39[a]	19.01[a]	64.45[a]	85	29.4	121
S.E of mean	±0.17	±0.16	±3.32		±3.1	±4.6

*Means with common letters are not significantly different at the 5% level, according to Duncan's Multiple Range Test.

(b) Flue-cured

Flue-cured tobacco variety N.C 95 was introduced in 1962 from Costa Rica and was recommended for commercial growing in 1966. Gradually the variety became popular among growers and since the last decade it was considered as standard in the evaluation of newly introduced varieties. Selection together with improved cultural practices led to an increase in cured leaf yield. Thus the average yield increased from 1184.5 kg to 1658.3 kg per hectare (500 to 700 kg/arpent), (Anon 1982). The highest cured leaf yield obtained at Richelieu E.S was in the 2nd season of 1981 when variety Speight G-41 achieved a yield of 3.00 t/ha. Other varieties like S.C 66 and Speight G-28 released for commercial growing did not gain the preference of growers. Among the other varieties introduced recently (including a new introduction of N.C 95 from the Republic of Panama), the performance of those under trial in 1984 is presented in Table 2.

Variety Speight G-41, since its introduction in 1980, proved to be a better variety than N.C 95 in terms of leaf yield and quality (price per unit weight of cured leaves). However, recently it was found to be susceptible to "Potato Virus Y" and will not be released for large scale growing. Coker 347 is another promising variety which has achieved a good yield of high quality tobacco. It also shows tolerance to "weather fleck", a physiological problem which has been affecting N.C 95 plantations.

TABLE 2

COMPARATIVE PERFORMANCE OF 12 FLUE-CURED TOBACCO VARIETIES UNDER TRIAL IN BOTH SEASONS OF 1984†

	Cured leaf yield (t/ha)		*Grade Index Rs/kg*		*Gross Returns '000 Rs/ha*		*Mean No of marketable leaves/plant*		*Plant height (cm)*	
	1st season	*2nd season*	*1st season*	*2nd season*	*1st season*	*2nd season*	*1st season*	*2nd season*	*1st season*	*2nd season*
N.C 95 ...	1.70[de]	1.72	33.05	41.08	55.99[e]	70.71	15.6	17.3	83[bc]	95[a]
Speight G-28	1.88[abcde]	1.82	34.99	41.10	65.88[abc]	74.65	16.4	19.4	83[bc]	81[abcd]
Coker 258 ...	2.08[ab]	1.60	32.92	41.66	68.09[ab]	66.46	16.3	17.7	90[ab]	76[cd]
Coker 298 ...	1.93[abcd]	1.80	32.18	40.74	62.28[bc]	73.13	16.1	18.4	75[c]	79[bcd]
Coker 347 ...	2.00[abc]	2.14	36.48	42.11	73.01[a]	89.88	16.8	19.0	90[ab]	84[abcd]
Coker 411 ...	2.15[a]	1.62	34.38	40.34	73.72[a]	65.17	17.3	18.1	81[bc]	73[d]
Mc Nair 944	1.87[abcde]	1.96	32.19	38.07	60.24[bc]	74.54	16.0	18.7	84[bc]	85[abcd]
N.C 13 ...	1.73[cde]	1.76	34.96	40.75	60.24[bc]	71.75	16.5	18.6	86[abc]	89[abc]
N.C 89 ...	2.04[ab]	1.80	33.99	42.65	69.23[ab]	77.34	14.8	17.7	81[bc]	78[bcd]
N.C 95* ...	1.79[bcde]	1.76	33.27	40.44	59.15[bc]	70.91	15.7	18.0	86[abc]	84[abcd]
N.C 2326 ...	1.63[e]	1.90	35.24	41.15	57.41[e]	78.15	16.3	19.4	98[a]	93[ab]
Speight G-41	2.08[ab]	2.14	35.59	42.79	74.05[a]	91.14	16.4	18.3	89[ab]	83[abcd]
S.E of mean±	0.09	0.17	1.03	0.88	3.19	7.02	0.5	0.57	3.7	3.6

†In any column, figures followed by common letter(s) indicate Duncan Multiple Range Groupings which do not differ significantly at the 5% level.

*This is a newly introduced stock of variety N.C 95.

FERTILISATION

Different rates and combinations of N, P and K fertilizers have been tried previously and recommendation for flue-cured tobacco is to use 25-30 kg N/ha as Sulphate of Ammonia, 75-90 kg P_2O_5/ha as Triple Super Phosphate and about 100 kg K_2O/ha as Sulphate of potash. About 50-60 kg N, 120 kg P_2O_5 and 120 kg K_2O per hectare are applied for air-cured tobacco. Growers are not allowed to use Muriate of Potash because of the adverse effect of chloride on the quality of tobacco. As a review, trials were set-up in both seasons of 1982 to investigate the effects of 5 rate of K-fertilizer (0, 50, 100, 150 and 200 kg K_2O/ha) and two formulations of N-fertilizer, Sulphate of Ammonia (21%N) and Calcium Ammonium Nitrate (26%N) at 30 kg N/ha and their interactions on the yield and quality of flue-cured tobacco variety N.C 95. The effect of the different treatments on the yield of cured leaves in the 2nd season is presented in Table 3. There was no significant difference (at the 5% level) on the yield and quality between the treatments and their interactions, but plots receiving Sulphate of Ammonia achieved higher cured leaf yields.

TABLE 3

YIELD OF CURED LEAVES (t/ha)

Main treatment / *Sub-treatment*	*K_2O (kg/ha)* 0	50	100	150	200	*Sub-treatment mean*	*S.E. of mean*
Sulphate of Ammonia ...	1.44	1.64	1.25	1.94	1.57	1.57	±0.18
Calcium Ammonium Nttrate ...	1.02	1.04	0.98	1.23	1.30	1.11	
Main treatment mean ...	1.23	1.34	1.12	1.58	1.44		±0.23

TOPPING TRIALS

It is known that removal of the flowerhead stimulates upper and middle leaves to expand, thus causing an increase in yield. Consequently, early removal of the flowerhead should maximise this effect. With this objective, during 1982-83, flue-cured tobacco variety N.C. 95 was topped at budding, extended bud, first flower of full flowering to study the influence of topping stage on yield and quality. A summary of results is presented in Table 4.

Though, there was a trend for the cured leaf yield to decrease as topping was delayed, there was no significant difference between the treatments. It was also much easier to remove the flower head at the extended bud stage.

TABLE 4

EFFECT OF TOPPING AT DIFFERENT STAGES OF FLORAL DEVELOPMENT

Topping at	*Cured leaf yield (t/ha)*	*Grade index (Rs/kg)*	*Gross returns (,000 Rs/ha)*
Early bud	1.697	34.43	58.420
Extended bud ...	1.550	34.01	52.145
1st flower	1.539	33.23	51.601
late flowering ...	1.460	34.00	49.834

SUCKER CONTROL

When the flowerhead is removed, axillary buds (suckers) develop and non-suppression of sucker-growth result in reduced yield. In Mauritius, this essential cultural practice is traditionally a manual operation which besides being laborious can cause damage to the plant. Hence the use of chemicals as sucker-control agents has been recently investigated.

The efficacy of two systemic chemicals, "O.M. 30" (active ingredient, a.i: diethanolamine salt of maleic hydrazide) and "Tamex" (a.i: 4—(1, 1— dimethylethyl)—N—(1— methylepropyl)—2, 6— dinitrobenzamine, common name Butralin) alone and in combination with a contact chemical "Antak" (a.i: n—Decanol) was assessed in the 2nd season of 1981 and in both seasons of 1982. The trials were carried out on conventionally topped flue-cured tobacco variety N.C. 95.

TABLE 5

EFFECT OF SUCKER CONTROL CHEMICALS ON YIELD AND QUALITY OF FLUE-CURED TOBACCO C.V. N.C 95

Treatment	*Cured leaf yield (t/ha)*	*Grade index (Rs/kg)*	*Gross returns ('000 Rs/ha)*
Control (Hand-suckering) ...	2.257	36.38	82.510
Tamex*	2.563	34.57	89.617
Antax + Tamex	2.347	34.02	80.037
O.M. 30*	2.350	35.17	82.510
Antak + O.M. 30 ...	2.493	34.24	85.390
Antak*	2.275	34.07	77.440

*Two applications at one week interval.

Suckers in the control plots were manually removed at weekly intervals and 5 to 8 rounds had to be effected per crop. Good sucker control was obtained with the chemicals. As shown in Table 5, plots chemically treated for sucker control tend to achieve higher cured leaf yields than the control plots mainly because of the production of heavier leaves. There was no marked difference in the quality (price per unit weight) of cured leaves from the various treatments though leaves from the control plots scored the highest grade index.

"ETHREL" AS A RIPENING AGENT FOR FLUE-CURED TOBACCO

The use of 2 chloroethyl phosphonic acid ("Ethrel") as a ripening agent for flue-cured tobacco leaves was studied during the last few years. Results vary with seasons, weather conditions and rate of application. In general, when applied after 3-4 reapings, "Ethrel" at the rate of 5 ml/l of water enables harvest of the remaining leaves in 2 more rounds within 10 days; the first and most important 3 days after treatment when about 75% leaves may be harvested and the second 7 days later. Also leaves started to yellow in the field so that a reduction in curing time resulted. However, in the 1st season of 1984, plots treated with 'Ethrel' showed a decrease in yield (about 15%) and an increase (about 13%) in leaves with greenish tinge (MFG). In the same trial, leaves in untreated plots were harvested over a period of 39 days and 3 suckering rounds had to be effected. Consequently, late 2nd season plantations may be treated with "Ethrel" as reduction in yield will be outweighed by risks of crop losses during cyclonic periods.

TOBACCO GRADING

Grading of local tobacco is based primarily on colour; degree of damage or spotting and size (length) are secondary factors. Thus all flue-cured leaves of the same colour (e.g. lemon to light orange) will be classified as BUF (Bright Upper Flue-cured) and then subdivided into undamaged (BUFI) and damaged or spotted (BUF2) or for leaves between 20 and 33 cm in length, BUFS. This differs from the international practice of grading according to plant position which is relevant in so far as both the physical (e.g. size, texture, body) and chemical (e.g. nicotine, sugar content) properties of leaves vary according to their position on the stalk. Consequently modification of the grading system to include plant position as a major factor is being contemplated. Trials carried out during 1984 have shown that leaves can be easily separated into 3 groups namely

X group—Priming and Lugs
C group—Cutters
B group—Leaf and Tips.

A set of standards for the identification of each group has been established and the chemical composition of each group is the subject of current investigation.

As for other crops, research on tobacco is a continuous process designed to meet the industry's future needs and to cope with problems as they arise. Some trials, like variety tests, goes on year after year whilst new ones are put-up from time to time so as to ensure that the industry continues to meet local requirements with increasing efficiency.

REFERENCE

Anon. (1982). Tobacco Board, 50th Anniversary 1932-1982 pp. 12.

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Studies on individual bush yield for clonal selection in tea, Camellia sinensis (L) O. Kuntze

by

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and

S. N. NAIDU—Scientific Officer (Agronomy)

RESUMÉ

Les analyses statistiques furent entreprises sur les données se rapportant aux plantes de thé en vue des travaux de sélection à la Station Expérimentale de Wooton. De vingt-quatre caractères étudiés, six furent retenus sur la base de leur valeur pour la sélection. Une analyse des correlations démontre que le nombre de tiges et le poids de 100 tiges ont des effets directs, prononcés et positifs, sur le rendement. Il apparait aussi que le rendement annuel de la plante peut être prédit avec une précision raisonnable à partir des observations faites sur les premières dix à quinze cueillettes après la taille.

SUMMARY

Statistical analyses were undertaken on data pertaining to bushes identified for clonal selection work at Wooton Tea Experimental Station. Among twenty-four characteristics investigated, six were found suitable as selection criteria. Path coefficient analysis points to the strong positive direct effects on yield of number of plucked shoots per bush and 100-plucked shoot weight. It was also found that annual green leaf yield of a tea bush could be predicted fairly precisely from observations on the first ten to fifteen plucking rounds after pruning.

INTRODUCTION

The tremendous wealth of variability in existing mature seedling commercial tea plantations is widely recognised (Kulasegram, 1980) and several selection criteria or procedures have been developed to identify suitable motherbushes that would eventually produce high yielding clones. Individual bush yield, in combination with other criteria, has been used since very long. Wellensiek (1938) suggested that selection be based on individual bush yield and pointed out that about six rounds of plucking should give the requisite degree of accuracy. Tubbs (1938, 1939) and Eden (1941) in Sri Lanka recommended the yield of seedling bushes as a criterion for selecting high yielding clones, though Tubbs later (1946) warned that environmental and inherited contributions to yield could not be normally distinguished. Sukarja et al (1977) in Indonesia reported that among other criteria, bushes are selected on the basis of flush weight for 15 pluckings. In an attempt to develop an improved selection procedure, Cannell et al (1978) studied the yields of individual tea bushes within mixed-genotype commercial stands, as influenced by non-genetic interplant competition and environmental hererogeneity, and recommended that bushes which performed better than expected, when compared to their neighbours, should be selected.

Work on tea clone selection programme was initiated in Mauritius around the late 1950's, and one clone, VP 1 H, which was then selected, has so far been propagated on a rather large scale. A new programme was started in 1981, along the guidelines suggested by the consultants of the Harrisons Fleming group. However, the lack of published literature on selection criteria and procedures that have been adopted locally has led to exclusive reliance on results obtained elsewhere. This paper attempts to present the results of observations on individual bush yields of mother bushes selected during 1981 to 1983, which may be useful for clonal selection work.

MATERIALS AND METHODS

Observations were taken on unshaded mature bushes, raised from seeds, within extensive fields at Wooton Tea Experiment Station (560 m above sea level, annual rainfall of 3800 mm, average daily sunshine of 6 hours and soil of Latosolic Brown Forest type). Details on the field plots are presented in Table 1. The fields were fertilised with complex N-P-K 22.5—7.5—7.5 at the rate of 650 kg per hectare in October and 500 kg per hectare of sulphate of ammonia in two split applications (December and February).

TABLE 1

CHARACTERISTICS OF FIELDS FROM WHICH TEA BUSHES WERE SELECTED (WOOTON, 1982 AND 1983)

Field	*Cultivar*	*Date planted*	*Acreage (ha)*	*Observation period*
2	Malayan	Jan 1950	1.67	1982 — 1983
3	Malayan	April 1983	1.20	1982 — 1983
4	Malayan	April 1950	1.99	1982 — 1983
6	Local	April 1950	1.40	1982 — 1983
8	Local	April 1951	2.21	1983 — 1984
9	Local	March 1951	1.30	1983 — 1984
15	Malayan	April 1953	1.38	1983 — 1984

Visual selection of healthy and vigorous bushes, surrounded by equally vigorous (and large) neighbours was done soon after pruning. Fields 2, 3, 4 and 6 were pruned in May 1982 and the others in May 1983 to a height of 45 cm.

Measurements were taken on each bush within the study plots in respect of the following characteristics: Main stem circumference, circumference of primary branches, the number of opened (or developed) buds at 2 months after pruning, weight of tippings, plucking table area of the selected bush and of the 4 nearest neighbouring bushes, weight of 'banjhi' shoots (i.e shoots with dormant buds) produced by the selected bush, number of plucked shoots, length of plucked shoot, length of first internode of the plucked shoot and leaf portions of plucked shoot. Tipping was performed during the months of October and November at 10—day intervals and plucking started in December and lasted till June of the following year. A 7-day plucking round was adopted and a total of 21—22 plucking rounds were effected.

The variation in green leaf yields among the bushes selected in the respective fields was determined. Correlation matrices were worked out for the yields of the individual bushes and the different characteristics mentioned earlier. Additionally the correlation was worked out between annual yield of individual bushes and yield accumulated over different periods of the one-year cycle.

TABLE 2

GREEN LEAF YIELD LEVELS AND VARIATIONS AMONG SELECTED MOTHERBUSHES

Field	*Mean yield (g)*	*Standard deviation ± (g)*	*Coefficient of variation (%)*	*Range*	
				Min.	*Max.*
2	881.6	152.0	17.2	598	1322
3	880.2	156.4	17.8	615	1187
4	718.8	174.1	24.2	376	1198
6	728.3	130.1	17.9	471	1142
8	429.0	121.8	28.4	173	740
9	407.3	96.8	23.8	264	670
15	404.0	78.8	19.5	193	603

RESULTS AND DISCUSSION

1. Variation among selected bushes

The yield level and the variation in individual bush yield among the selected bushes in the respective fields are summarised in Table 2. The mean bush yield over the observation period of 22 plucking rounds (extending from December to June) ranges from 404.0 to 881.6 grams. Bushes selected in 1982 from fields 2, 3, 4 and 6 had higher yields than those selected in 1983 from the remaining fields (fields 8, 9 and 15). It must, however, be pointed out that the latter bushes suffered adversely from strong winds that prevailed during the passage of cyclone Bakoly in early 1983.

The extent of variability present among the bushes is one of the major factors determining the likely success of a tea clonal selection programme. Data on variability presented in Table 2 show that bushes selected from field 8, 9 and 15 have, in general, a higher coefficient of variation with respect to yield compared to bushes selected in 1982. The coefficient of variation figures for selected bushes in fields, 2, 3, 4 and 6 indicate that substantial variation exists in those fields, which suggests that clonal selection work on such material can be expected to be fruitful. As pointed out earlier, the amount of variation reported refers to bushes selected during a first screening on the basis of bush vigour, and a higher coefficient of variation would have been observed in the case where all the bushes from each field would have been considered. This makes an even stronger case for selection work in the tea fields studied.

2. Correlation studies on bush characteristics for selection work

Data recorded on individual bushes for the characteristics listed in Table 3 and their correlations with yield of green leaf, are presented for the fields studied in respect of data collected during the period December to June (test period for fields 2, 3, 4 and 6). On the basis of the magnitude of the correlation coefficients and the consistency of the relationship over the various fields, the following bush characteristics were retained as potentially important contributors to bush yield, either directly or indirectly: (i) weight of tippings, indicative of the bush ability to recover from pruning, as measured by the leaf yield obtained during the first seven months following pruning, (ii) index of competitive ability, as measured by the ratio of bush yield to average yield of its four nearest neighbours; this is an interesting characteristic, particularly in the case where clones are to be used for filling in vacancies in existing plantations, (iii) number of plucked shoots, (iv) area of plucking table, (v) weight of 100 plucked shoots, and (vi) length of plucked shoot as measured from bud-tip to a point one centimetre below the lower leaf axil. The last four characteristics have an immediate relationship with the yield of the bush.

TABLE 3

CORRELATION OF INDIVIDUAL BUSH YIELD AND OTHER CHARACTERS

Character	*Field 2*	*Field 3*	*Field 4*	*Field 6*
1. Circumferences of main stem ...	0.319	0.487	—0.107	0.230
2. Area of main stem	0.309	0.512	—0.137	0.240
3. Σ Circumference primary branches ...	0.333	0.339	0.145	0.325
4. Σ Area of primary branches ...	0.389	0.282	0.137	0.104
5. Ratio of main stem area to Σ area of primary branches	0.043	0.362	—0.251	0.244
6. Ratio Σ circumference primary branches: to circumference main stem ...	—0.018	—0.174	0.272	0.162
7. Total number of buds on bush ...	0.346	0.738	0.681	0.471
8. Yield per unit plucking table area ...	0.047	—0.083	0.628	—0.186
9. Area of plucking table	0.784	0.683	0.498	0.752
10. Σ yield of 4 neighbourgs	0.598	0.490	0.645	0.668
11. Σ area of plucking table of 4 neighbours	0.123	0.135	0.249	0.350
12. Ratio of yield of bush to average yield of neighbours	0.663	0.430	0.700	0.659
13. Ratio Area of bush to average area of neighbours	0.611	0.409	0.191	0.581
14. Number of plucked shoots	0.948	0.908	0.976	0.945
15. Weight of 100 plucked shoots ...	0.504	—0.078	0.560	0.372
16. Weight of ' Banjhi ' (dormant) shoots ...	0.655	0.606	0.787	0.941
17. ' Banjhi '%	0.026	—0.062	—0.054	0.634
18. Length of plucked shoot	0.662	0.245	0.583	0.256
19. Length of first internode of shoot ...	0.213	0.061	0.568	0.155
20. Leaf portions% plucked shoot ...	—0 220	0.346	—0.161	0.384
21. Weight of tippings	0.875	0.718	0.837	0.841
22. Pubescence of first leaf of shoot ...	0.314	0.127	0.122	—0.159
23. Ratio yield neighbours to area of neighbours	0.272	0.464	0.593	0.249
24. Number of plucked shoots per unit area plucked	—0.084	0.015	0.370	—0.298

It is worth noting that such characteristics as circumference of main stem and that of primary branches are not well correlated with yield of the bush. Originally these two characteristics were thought to be a fair indication of bush vigour and hence the yielding ability of the bush; accordingly the first selection in the field was based on vigour as assessed on these two characteristics. The present data do not support these criteria and point to the need for a revision of selection criteria to be adopted in the initial phase of similar programmes.

3. Path coefficient analysis

Yield is a complex character associated with several inter-related component characters. Under these conditions, the simple correlation coefficients computed between yield and a particular component or bush characteristic reflect both the direct effect of the character on yield as well as the indirect effect (s) via other component character (s) and are thus unreliable in working out selection indices. Path coefficient analysis allows for the partitioning of correlation coefficient into direct and indirect effects (Dewey and Lu, 1959), thereby giving a better insight into the association of yield with its components and with some bush charactteristics.

Data were collected on the thirty selected bushes in field 2 and the correlation coefficients worked out (Table 3); however, for this detailed analysis, only six characters were retained on the basis of the strength of their relationship with yield. These are (i) number of plucked shoots, (ii) 100-plucked shoot weight, (iii) area of plucking table, (iv) weight of tippings (v) ratio of bush yield to average yield of 4 neighbours and (vi) mean length of plucked shoot. Table 4 shows the estimates of the direct and indirect effects of those factors on yield.

TABLE 4

PATH ANALYSIS SHOWING THE DIRECT AND INDIRECT EFFECTS OF SIX CHARACTERS ON TEA YIELD

Characters	*Indirect effects via*						*Correlation value with yield*
	(1)	(2)	(3)	(4)	(5)	(6)	
1. No. plucked shoots	(0.864)	0.066	0.033	0.025	—0.046	0.006	0.947
2. 100–plucked shoot weight ...	0.180	(0.316)	0.255	0.017	—0.040	0.005	0.503
3. Area plucking table	0.586	0.165	(0.049)	0.025	—0.046	0.005	0.730
4. Weight of tipings	0.678	0.168	0.038	(0.031)	—0.047	0.006	0.875
5. Ratio of bush yield to av. neighbour yield	0.522	0.165	0.029	0.019	(—0.077)	0.005	0.663
6. Av. length of plucked shoot ...	0.492	0.151	0.024	0.018	—0.034	(0.011)	0.662

Note: (i) Figures in parentheses are direct effects on yield
(ii) Residual effect negligible

Results indicate strong direct effects on yield in the case of number of plucked shoots per bush (0.864) and 100-plucked shoot weight (0.316). The other four characters have very low direct effects, but were in all cases positive except for the ratio of bush yield to average yield of neighbouring bushes, which had a low negative direct effect. The high correlations of these latter four characteristics are explained by the relatively high indirect effects they have on yield via the first two characters (Table 4, columns 1 and 2); such indirect effects were stronger via number of plucked shoots per bush than via 100-pucked shoot weight for all the other characters observed.

4. Prediction of yield potential of selected mother-bushes

As the tea crop is cultivated essentially for the production of green leaf, it is quite natural that a measure of the yielding ability of the selected motherbushes be determined at an early stage in the clonal selection programme. However, such a criterion requires data from multiple harvests over extended periods, which thus implies a considerable amount of manpower, time and funds. To circumvent these 'difficulties', it was felt desirable to obtain an assessment of an annual yield potential based on a restricted number of plucking rounds, preferably earlier in the production year.

To that effect, data were collected for 30 selected motherbushes in each of five fields in respect of annual green leaf yield as well as the corresponding yield over a set of different periods of specific duration. These time periods are listed in the first column of Table 5, which presents the coefficients of correlation between the annual yield observed and the yield obtained for the different time periods.

TABLE 5

CORRELATION BETWEEN YIELDS COMPUTED FOR DIFFERENT LENGTHS OF PERIODS AND ANNUAL YIELDS

	Field 3	*Field* 6	*Field* 8	*Field* 9	*Field* 15
1. ≶ first 5 plucking rounds ...	0.868	0.884	0.894	0.607	0.917
2. ≶ first 10 plucking rounds ...	0.877	0.934	0.851	0.854	0.943
3. ≶ first 15 plucking rounds ...	0.905	0.957	0.915	0.894	0.926
4. ≶ first 20 plucking rounds ...	0.931	0.956	0.901	0.913	0.928
5. ≶ first 25 plucking rounds ...	0.944	0.965	0.899	0.918	0.920
6. ≶ 3 summer months yield ...	0.880	0.938	0.846	0.986	0.904
7. ≶ 6 plucking rounds (summer) ...	0.849	0.912	0.905	0.816	0.885
8. ≶ 10 plucking rounds (summer) ...	0.861	0.913	0.830	0.882	0.927
9. ≶ 3 winter months yield ...	0.866	0.684	0.480	0.355	0.514
10. ≶ 6 plucking rounds (winter) ...	0.841	0.716	0.589	0.399	0.426
11. ≶ 10 plucking rounds (winter) ...	0.958	0.744	0.431	0.318	0.470

Results indicate that a reliable prediction of annual yield cannot be obtained from observations made during winter months. However, on the basis of yield figures obtained during short periods in summer, satisfactory projections can be worked out as the relationship with the annual yield is both strong and stable across the different tea fields. Similarly, good results may be achieved from data collected over short periods at the start of the production year. Predictions based on the first 5 plucking rounds are also possible but these show a fair degree of unstability across the fields. Thus, it would be more reasonable to predict the annual yield potential of a selected bush on the basis of the first ten to fifteen plucking rounds—after pruning.

CONCLUSION

The extent of yield variability, as assessed in the fields studied at Wooton, indicates that clonal selection on such material remains a promising avenue in the search for improved stock to be used in future plantations or fields to be rehabilitated. Additionally, it is sugested that plantations outside Wooton, which have been raised from opened-pollinated seed, may also prove worthy material for selection work.

Correlation studies have indicated that criteria for selection may be limited to only six bush characteristics viz. number of plucked shoots, 100-plucked shoot weight, area of plucking table, weight of tippings, ratio of bush yield to average yield of neighbours and average length of plucked shoot. This follows from their strong correlation with yield of green leaf.

In the case where constraints of time and manpower may operate, as may be the case when data need to be collected in planters' fields, this set of characteristics could be reduced to two, viz. number of plucked shoots and 100-plucked shoot weight. The latter two characteristics have been shown to bear strong positive direct effects on yield whereas the high correlations of the remaining four have been found to reflect only small direct effects on yield.

It is also possible to restrict the observation period for yield data to the first ten to fifteen plucking rounds after pruning, which usually extend over the period December to May. Plucking should preferably be undertaken at weekly intervals. This approach would permit the study of a larger number of bushes, and help accelerate the process of clonal selection.

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REFERENCES

1. Cannell, M. G. R., Njuguna, C. K., Ford, E. D. and Smith, R. (1977). Variation in yield among competing individuals within mixed genotype stands of tea: A selection problem. J. Appl. Ecol., *14*: 969-985.
2. Dewey, D. R. and Lu, K. H. (1959). A correlation and path coefficient analysis of components of crested wheatgrass seed production. Agron. J. *51*: 515-8.
3. Eden, T. (1941). The selection of high-yielding tea bushes for vegetative propagation. Tea Quart., *14*: 98-102.
4. Kulasegram S. (1980). Technical developments in tea production. Tea Quart., *49*: 157-83.
5. Sukarja, D. and Munir-Suprapto, A. (1977). Selection of tea mothertrees on the Kertamanah Estate. Menara Perkebunan, *45*: 219-225.
6. Tubbs, F. R. (1938). Report of the plant physiologist. Ann. Rep. Tea Res. Inst. Ceylon for 1937: 44-62.
7. Tubbs, F. R. (1939). Improvement of plant material—Propagation of tea by single internodes in peat moss. Tea Quart., *12*: 38-51.
8. Tubbs, F. R. (1946). Tea selection. Tea Quart., *18*: 59-65.
9. Wellensiek, S. I., (1938). Researches on quantitative tea selection. iv. Mother tree selection. (Dutch with Eng. summ.) Arch. Thee cult., *12*: 2-70.

Fertilizer Experiments in Tea (1978 - 1984) III. Nutrient Status of Tea Soils

by

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RESUMÉ

Des expériences d'engrais sur le thé démontrent que le sol sous cultivation de thé à Wooton a une plus haute capacité de fournir des éléments nutritifs que ceux de Verdun et de Plaine Sophie. Les deux derniers sols sont fortement lessivés et contiennent comparativement de faibles niveaux d'azote, de phosphore, de cation échangeable et de matières organiques. Ils ont aussi une forte capacité de P-fixation comparé au sol de Wooton.

Les résultats prouvent aussi que le pH du sol diminue avec un apport élevé d'azote.

SUMMARY

Fertilizer experiments in tea show that the tea soil of Wooton has higher nutrient availability potentials for crop nutrition than those of Verdun and Plaine Sophie. The latter two soils are strongly leached mature soils and contain comparatively low levels of N, P, OM and exchangeable cations and are high P-fixing soils.

The results also demonstrate that increasing rates of applied N. fertilizer lower the pH of the tea soils.

INTRODUCTION

Soils are natural media for the growth of plants. The capacity of soils to store and to supply nutrient elements for plant nutrition is a fundamental problem of crop production. All types and groups of soil have a specific level of natural fertility. Under identical climatic conditions this level is determined by many factors: the charactteristic of parent rock, the physical, physico-chemical and biochemical properties of the soil and to a large extent, the presence of reserves of essential elements for plant nutrition. Intensive cultivation of land often results in rapid depletion of natural fertility whereby the production capacity of the soil is greatly reduced. An adequate supply of plant nutrients, both organic and inorganic, will go a long way towards ensuring success in the production of crops.

MATERIALS AND METHODS

During the period 1978 to 1984, fertilizer experimentswere carried out in nature tea plants at Wooton Tea Experiment Station and in young tea plants at Verdun and Plaine Sophie. The experiments were designed by Mr. S. N. Naidu and conducted by Mr. Y. Boodoo, both of Agronomy Division (Boodoo 1986).

EXPERIMENTS

Experiment 3A — Wooton Tea Experiment Station

"To determine the biological and economic optimum rate of N application at two levels of P and K". A split-plot design in five randomised blocks was used. Treatments consisted of five levels of N: 200, 250, 300, 350 and 400 kg N/ha/yr and two levels of PK i.e. (PK) 1: 30 Kg P_2O_5 + 30 Kg K_2O/ha/yr and (PK) 2: 90 Kg P_2O_5 +90 Kg K_2O/ha/yr.

Experiment 5C — Wooton Tea Experiment Station

"To determine the effect of time and frequency of application of P and K on the yield of tea at two N rates". The lay out was a split-plot design with four replicates. Treatments consisted of two levels of N: 150 and 300 Kg N/ha/yr, a low PK level of 30 Kg P_2O_5+30 Kg K_2O/ha/yr and a high PK level of 90 Kg P_2O_5+90 Kg K_2O/ha/yr.

Experiment XI

"To determine the effect of different rates of N application on the yield of tea at different levels of P and K". A split-plot design in four randomised blocks was used. Treatments consisted of four levels of N. 100, 200, 300 and 400 Kg N/ha/yr, one level of P: 90 Kg P_2O_5/ha/yr and two levels of K: 60 and 120 Kg K_2O/ha/yr.

This experiment was conductted on two soil types.

A: Latosolic Brown Forest (Wooton Tea Experiment Station)

B. Humic Ferruginous Latosols (Verdun).

Experiment XII

"To determine the effect of different rates of N on the yield of clone VPIH at two levels of P and K". This experiment was laid out at Plaine Sophie in a clonal field of VPIH pruned November, 1981. A split-plot design in four replicates was used. Treatments consisted of four levels of N: 250, 300, 350 and 400 Kg N/ha/yr and two levels of PK. i.e. (PK) 1:30 Kg P_2O_5+30 Kg K_2O/ha/yr and (PK) 2:90Kg P_2O_5+90 Kg K_2O/ha/yr.

In experiments IIIA, XIA, XIB and XI split application of N were carried out in September, December and February, PK were given a single dressing in September in each year of the pruning cycle. A different fertilizer regime was used in experiment VC. N. rates were kept constant, PK levels were varied as:—

(i) PK applied annually throughout pruning cycle

(ii) 3 year's PK requirements at start of cycle

(iii) 3 year's PK requirements at end of cycle.

It is important to point out that these experiments were set up primarily to study the agronomic aspects of tea cultivation but it was thought important to study simultaneously the nutrient characteristics of the soils of the experimental sites. Consequently soil samples from the experimental fields were collected by the Agronomy Division and were analysed by the Agricultural Chemistry Division.

Soil samples were collected before fertilizer applications twice yearly from experimentts IIIA, VC, XIA and XIB, and at the end of cycle from experiment XII. Samples were taken at a depth of 0 — 20 cm for surface soil and 20 — 60 cm for sub surface soil from each plot. The samples were air-dried in a well ventillated room and were then ground to pass through a $<$ 2mm sieve on which the chemical analysis were performed.

It is also important to note that no statistical analysis of the data of soil test values has been carried out. The discussion which follows, points out the general trend observed regarding the nutrient status of the tea soils.

ANALYSIS OF SOIL

The soil pH is determined in the supernatent of a 1: 2.5 soil water mixture, equilibrated for one hour and measured with a glass electrode.

Total N is determined by Kjeldahl method. In this method 3 g soil is digested for three hours in the presence of digestion mixture composed of Na_2SO_4+ $CuSO_4$+Se+40 cm^3 of concentrated H_2SO_4. The ammonia is distilled off and collected in a 2% Boric acid solution which is then back titrated with 5 mM H_2SO_4. .

Bray and Kurtz method is used for extraction of available P. Soil sample is shaken with 0.03M NH_4F +0.1M Hcl extracting solution (50 cm^3/5g) for one minute and P in the extract is measured colorimetrically with ammonium molybdate-Ascorbic acid reagent.

Exchangeable K, Ca, Mg are extracted from the soil by leaching the sample with 1M ammonium acetate pH 7.0 (100 cm^3/5g). K is determined with Flame photometer and Ca and Mg with Atomic Absorption Spectrophotometer (A.A.S.).

Modified Walkley and Black method is used for the estimation of Organic Carbon in soil. Organic Carbon in the soil is oxidised with $K_2Cr_2O_7$ and H_2SO_4 using the heat of dilution of the reaction. It is then diluted with 0.4% $BaCl_2$ solution and the colour intensity is measured with SP.6-500 Spectrophotometer at 620 nm.

Active Fe. Al and Mn are extracted with 0.2M acid ammonium oxalate pH 3.0 and are determined with A.A.S.

RESULTS AND DISCUSSIONS

Nutrient characteristics of the tea soils

The soils of Verdun and Plaine Sophie are developed on the Intermediate Lava and are classed into Humic Feruginous Latosol. The soil at Wooton is developed on Late Lava and belongs to the Latosolic Brown Forest Soil group. This soil group contains comparatively higher levels of natural nutrient elements (Parish and Feillafe 1965). However all the tea soils of the experimental sites are very strongly acidic. The soil pH of Wooton, Verdun and Plaine Sophie is less than 4.5. It is reported that tea grows well in soil of pH $<$ 5.0 (Sivasubramanian and Talibudeen 1971). But according to De Geus (1978) the normal pH of good tea soils is pH $<$ 6.0. The results obtained in these experiments show that the pH of the tea soils of Wooton, Verdun and Plaine Sophie are reduced with the increasing rates of applied N fertilizer as shown in table I.

TABLE I

EFFECT OF DIFFERENT N RATES ON SOIL pH

pH 1: 2.5

N rates Kg N/ha	*Wooton (Expt. XIA)*	*Verdun (Expt. XI B)*	*Plaine Sophie (Expt. XII)*
0*	3.9	3.7	4.0
100	3.6	3.4	—
200	3.4	3.3	—
250	—	—	3.8
300	3.4	3.3	3.7
350	—	—	3.6
400	3.3	3.2	3.6

* Before any fertilizer application

— Dashes indicate that N rates are not included in experiments at the respective sites

TOTAL NITROGEN AND ORGANIC MATTER

It is observed that increasing rates of N fertilizer used in the experiments do not increase proportionally the soil total N content in any soil type (Table II). The soil of Wooton is found to have higher potentials for N availability for tea nutrition than the Verdun and Plaine Sophie tea soils. At a common rate of 300 kg N/ha applied to the soil of Wooton, Verdun and Plaine Sophie, the amount of total N available in these soils are 0.35% (average of expts IIIA, VC and XIA), 0.25% and 0.19% respectively. Moreover at 40 kg N/ha treatment, no significant increase in the level of total N content in these soils is observed. However the effect of N fertilizer is more pronounced in Wooton tea soil than those of Verdun and Plaine Sophie. The organic matter content is 7.15% in the tea soil of Wooton. The Verdun and Plaine Sophie tea soils contain 5.96% and 3.62% respectively. Consequently the rate of N mineralisation and hence the availability of soil N for tea nutrition seem to be much higher in Wooton tea soil and least in the soil of Plaine Sophie.

TABLE II

EFFECT OF N RATES ON N (%) CONTENT OF TEA SOILS

Experiments		*Rates — kg N/ha*						
		N100	*N150*	*N200*	*N250*	*N300*	*N350*	*N400*
IIIA	Wooton	—	—	0.37	0.35	0.36	0.33	0.38
VC	Wooton	—	0.34	—	—	0.33	—	—
XIA	Wooton	0.39	—	0.37	—	0.37	—	0.34
XAB	(Verdun)	0.25	—	0.24	—	0.25	—	0.23
XII	(P. Sophie)	—	—	—	0.17	0.19	0.19	0.18

— Dashes indicates that N rates are not included in experiments at the respective sites

PHOSPHORUS

The amount of available P presents in the tea soils of Verdun and Plaine Sophie is lower than the Wooton soil. High soil acidity and low content of soil organic matter are some of the factors influencing the availability of P either from the native or applied sources. Solubilisation of Fe, Al and Mn occurs in the soil solution at low soil pH. Consequently the soluble P gets fixed and is rendered unavailable or slowly available to plant growth (Katyal and Sharma 1979). This process is probably operating in Humic Ferruginous latosol which is a strongly leached soil group. The soil response to applied P fertilizer varies widely among the three tea soils. At 30 kg P_2O_5/ha treatment, the soil of Plaine Sophie contains lower level of available P than Wooton. Similarly, at a common P treatment of 90 kg P_2O_5/ha, the tea soil of Wooton retains the highest quantity of P in available form than the other two tea soils (Table III).

TABLE III

AVAILABLE P (mg/kg) IN TEA SOILS

Experiments	Soil types			Kg P_2O_5/ha P: 30	Kg P_2O_5/ha P: 90
IIIA	Wooton	...	L.B.F. ...	35	43
VC	Wooton	...	L.B.F. ...	38	42
XIA	Wooton	...	L.B.F. ...	—	47
XIB	Verdun	...	H.F.L. ...	—	12
XII	P. Sophie	...	H.F.L. ...	9	11

L.B.F. — Latosolic Brown Forest Soil

H.F.L. — Humic Ferruginous Latosol

— Dashes indicate that P_2O_5 rates are not included in the respective experiments.

The differences in response of these soils to applied P may be also due to the differences in P-fixing capacities of the soils. Because the soils of Mauritius are principally Latosols and Lateritic soils, the only minerals are Kaoline and iron and aluminium oxides of varying degrees of hydration which hold or fix phosphate very strongly (Parish 1966).

POTASSIUM

K ions are highly mobile cations in a soil system, and hence have great tendency to be leached down to the lower soil horizon. The tea soils of Wooton, Verdun and Plaine Sophie contain variable amounts of exchangeable K as is shown in Table IV. Verdun and Plaine Sophie contain lower amount of exchangeable K than Wootton tea soil.

TABLE IV

EFFECT OF K TREATMENTS ON EXCHANGEABLE K (me%) CONTENT OF SOILS OF WOOTON, VERDUN AND PLAINE SOPHIE

Experiments				Kg K_2O/ha K 30	K 60	K 90	K 120
IIIA	Wooton	...	...	0.31	—	0.49	—
VC	Wooton	...	...	0.34	—	0.48	—
XIA	Wooton	...	...	—	0.38	—	0.52
XIB	Verdun	...	...	—	0.18	—	0.19
XII	P. Sophie	...	...	0.14	—	0.17	—

— Dashes indicate that K_2O rates are not included in the experiments at the respective sites.

It is found that the soils of Verdun and Plaine Sophie contain about half as much exchangeable K as the amount present in Wooton soil. It can be concluded that the strongly weathered soils of Verdun and Plaine Sophie have low potentials for K exchangeability than the immature tea soil of Wooton. However a substantial increase in exchangeable K is observed in the three soils.

EXCHANGEABLE Ca AND Mg AND MICRO ELEMENTS

Humic ferruginous Latosol is the soil group to which belong the tea soils of Verdun and Plaine Sophie. This soil group is mature and strongly weathered in nature. Advance leaching losses of exchangeable cations have occurred (Parish and Feillafé 1965). It has low capacities of retaining mineral nutrients due to the depletion of soil fertility during the weathering process. Exchangeable Ca ranges from 0.12 me % to 0.67 me % with an average value of 0.36 me %, and exchangeable Mg averages 0.26 me % in the range of 0.18 me % to 0.46 me % in the tea soil of Verdun. Wooton soil contains higher level of exchangeable Ca and Mg. Exchangeable Ca averages 0.51 me % with the range of 0.27 —0.91 me % and exchangeable Mg ranges 0.13—

0.85 me % with an average value of 0.61 me %. Although no micro-elements are added along with the fertilisers, the native level of Fe, Al and Mn in the two soil groups shows wide variation. It is observed that Latosolic Brown Forest (Wooton soil) contains active Fe in the range of 1.80–3.70 %, active Al between 0.09 and 1.85% and Mn varies from 200 to 550 mg/kg. The Humic Ferruginous Latosol varies in these micro elements from 0.55 to 0.74 % for active Fe, 0.50 to 0.96 % for active Al and active Mn from 130 to 603 mg/kg. The wide variation of these micro elements in the two soil groups can be attributed to the nature and weathering process of the parent rocks.

CONCLUSION

It is evident from the present study that the tea soils of the experimental sites are strongly acidic. Higher levels of N, P, K exchangeable Cations and organic matter are present in the soil of Wooton than in Verdun. The tea soil of Plaine Sophie is low in these nutrient characteristics. Evidently, the nutrient availability potentials of the tea soils of Wooton, Verdun and Plaine Sophie are in the order: Wooton > Verdun > Plaine Sophie.

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REFERENCES

Boodoo, Y. (1986). Fertilizer Experiments in tea (1978-1984). I. Yield and NPK requirements (in preparation).

De Geus, J. C. (1967). Fertilizer Guide for Tropical and Subtropical farming. Centre d'Etude de L'Azote, Zurich.

Katyal, J. C. and Sharma B. D. (1979). Role of micronutrients in crop production. Fertilizer News. Vol. 24 (9): 33-50.

Parish, D.H. and Feillafé, S.M. (1965). Notes on the 1: 100,000 soil Map of Mauritius—MSIRI. Occasional paper No. 22.

Parish, D.H. (1966). Sugar cane Fertilization—A summary of present practical knowledge. MSIRI. Technical Circular No. 28.

Sivasubramaniam, S. and Talibudeen, O. (1971). Effects of Aluminium on the growth of tea (Camellia sinensis) and its uptake of Potassium and Phosphorus. J. Sci. Fd. Agric. Vol. 22. 325-329.

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Fertilizer Experiments in Tea (1978 - 1984)

Major and minor nutrients in the leaf

by

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RESUMÉ

Les résultats d'analyse pour les éléments N, P, K, Ca, Mg, Zn, Cu, Fe et Mn des échantillons de troisième feuille et de feuille d'entretien en provenance de 5 expériences agronomiques sont présentés. Les chiffres obtenus démontrent que le mois de Mai est plus propice à l'échantillonage des feuilles pour les besoins d'analyse chimique aussi bien que pour ceux concernant l'agronomie.

Les différents taux des 9 éléments précités ont été vus d'un oeil critique et commentés en profondeur ainsi que leur rôle dans le métabolisme de la plante de thé.

SUMMARY

Third and mature leaf samples from 5 agronomic experiments have been analysed for N, P, K, Ca, Mg, Zn, Cu, Fe and Mn and the average levels found are presented.

On the basis of the data obtained, May is found to be the best month for leaf sampling.

Detailed and critical views on the levels of the 9 different nutrients analysed for and their role in the tea plant, are also given.

INTRODUCTION

The economic importance of the tea plant, Camellia sinensis, lies in its leaves which are used to make the refreshing beverage we simply know as tea.

If the chemistry of the conversion of green leaf into black tea is known to some accuracy, it is less certain how the chemical composition of the made tea is related to the taste of the daily cup of tea.

The major elements nitrogen, phosphorus and potassium actively take part in foliage production thereby controlling yields. The host of minor elements detected in the tea leaves certainly take part in important physiological processes in the plant. Most of these processes, however, are still obscure and remain Nature's closely guarded secret.

In an attempt to find out how leaf production can be boosted up by rational fertilizer application agronomic experiments are carried out. Although such experiments have been going on for a certain number of years, the chemical composition of the leaves could be studied systematically only fairly recently when improved techniques and automated instruments became accessible.

Green leaves were taken from experimental fields and analysed for nine elements as listed below, with a view to compiling some data concerning the chemical constitution of tea leaves grown in Mauritius.

2. MATERIALS AND METHODS

2.1 From 1980 to 1983 a total of 4944 leaf samples were taken from tea agronomic experiments IIIA, VC, XIA at Wooton, XIB at Verdun and XII at Plaine Sophie. These experiments were conducted by Scientific Officer Y. Boodoo of the Agronomy Division.

Although the analytical results obtained were primarily destined for agronomic uses, advantage has been taken to use them for the purpose of studying the general trends of nitrogen, phosphorus, potassium, calcium, magnesium, zinc, copper, iron and manganese in third and mature leaves of the tea plant.

Statistical analysis of the data has not been performed and only trends based on average values have been looked into.

2.2 Some particulars of the experiments.

2.2.1 *Experiment IIIA*

Title: To determine the biological and economic optimum rate of nitrogen application at two levels of phosphate and potash.

Fertilizer treatments:

(a) Five nitrogen levels, viz: 200, 250, 300, 350 and 400 kg N/ha/yr.

(b) A low (phosphate+potash) level, viz: 30 kg P_2O_5+30 kg K_2O/ha/yr.

(c) A high (Phosphate+potash) level, viz: 90 kg P_2O_5+90 kg K_2O/ha/yr.

2.2.2 *Experiment VC*

Title: To determine the effect of time and frequency of application of phosphate and potash on the yield of tea at two nitrogen rates.

Fertilizer treatments:

(a) Two nitrogen levels, viz: 150 and 300 kg N/ha/yr.

(b) A low (phosphate+potash) level, viz: 30 kg P_2O_5+30 kg K_2O/ha/yr.

(c) A high (phosphate+potash) level, viz: 90 kg P_2O_5+90 kg K_2O/ha/yr.

With a given nitrogen application, each (phosphate +potash) combination was applied (i) throughout the pruning cycle as one treatment (ii) at the start of the cycle only as a second treatment and (iii) only at the end of the cycle as a third treatment.

2.2.3 *Experiment XI*

Title: To determine the effect of different rates of nitrogen application on the yield of tea at different levels of phosphate and potash.

Fertilizer treatments:

(a) Four nitrogen levels, viz: 100, 200, 300 and 400 kg N/ha/yr

(b) one phosphate level, viz: 90 kgP_2O_5/ha/yr.

(c) Two potash levels viz: 60 and 120 kg K_2O/ha/yr

Experiment XIA was the above experiment carried out at Wooton and Experiment XIB was a repeat at Verdun.

2.2.4 *Experiment XII*

Title: To determine the effect of different rates of nitrogen on the yield of clone VP1H at two levels of phosphate and potash.

Fertilizer treatments:

(a) Four nitrogen levels, viz 250, 300, 350 and 400 kg N/ha/yr.

(b) A low (phosphate+potash) level, viz: 30 kg P_2O_5+30 kg K_2O/ha/yr

(c) A high (phosphate+potash) level, viz 90 kg P_2O_5+90 kg K_2O/ha/yr

Experiments IIIA, XI and XII were fertilized in the same manner, viz: nitrogen was applied in three equal lots in September, December and February and phosphate and potash were applied in one lot in September.

Experiment VC had a different programme, as mentioned above under paragraph 2.2.2.

Experiments at Wooton involved mature tea established on latosolic brown forest soil, whereas the experiments at Verdun and Plaine Sophie involved young tea planted on humic ferruginous latosol.

2.3 *Leaf sampling*

Sampling was done in May and in December each year and third and mature leaf samples were taken each time. The third leaf is the one just after the pluckable "two and a bud" taken for tea manufacture. The mature leaf (also called maintenance leaf) is an old, well-formed existing leaf on the plucking table, fully exposed to the sun. The third leaf gives a good indication as to the nutrient status of the "two and a bud" fraction, whereas the mature leaf reflects the bush nutritional status.

2.4 *Leaf analysis*

Samples were dried at 80°C in a forced air oven, ground to pass through a mesh with holes 1.0 mm in diameter and analysed for nitrogen, phosphorus, potassium, calcium, magnesium, zinc, copper, iron and manganese. The first five elements are expressed as percentages of dry matter and the remaining four as mg per kg of dry matter.

For the determinations of N, P, K, the samples were digested in a mixture of sulphuric and perchloric acids using the aluminium block mass digestion technique. From the same digest nitrogen was measured by colorimetry using Nessler reagent, phoshorus by colorimetry as phosphomolybdic-acid and potassium by flame photometry. To determine the remaining 6 elements, the samples were dry-ashed and put in solution by means of hydrochloric acid. The elements were then measured by atomic absorption spectroscopy.

3. RESULTS AND DISCUSSIONS

3.1 *Nutrients in third and mature leaves*

There is a well-defined trend in the nutrient contents of these two leaves. For example it is noted that at any sampling time the third leaf contains more nitrogen, phosphorus, potassium, zinc and copper than the mature leaf. Magnesium is almost the same in both leaves. Calcium, however, is more in the mature leaf than in the third leaf.

Table 1 illustrates the observed trend.

TABLE 1

RATIOS OF ELEMENTS, THIRD LEAF TO MATURE LEAF

Nutrient	*Ratio*	*Nutrient*	*Ratio*
Nitrogen ...	1.1:1	Magnesium ...	0.9:1
Phosphorous ...	1.5:1	Zinc ...	1.8:1
Potassium ...	1.3:1	Copper ...	1.4:1
Calcium	0.5:1	— ...	—

Iron and manganese vary very widely in tea leaves, and it is not possible to compute the mean level. There is a tendency for the mature leaf to have more iron and manganese. That tendency however is not well defined. Table 2, below, computed from data collected from the control plot over the years, show how ill-defined the trend can be.

TABLE 2

RATIOS OF IRON AND MANGANESE, THIRD LEAF TO MATURE LEAF

Sampling time	*Iron ratio*	*Manganese ratio*
May 1980	0.72:1	0.99:1
Dec. 1980	0.67:1	0.37:1
May 1981	1.16:1	0.56:1
Dec. 1981	0.58:1	0.43:1
May 1982	0.78:1	0.41:1
Dec. 1982	1.94:1	1.39:1
May 1983	0.57:1	0.47:1
Dec. 1983	1.03:1	0.66:1

3.2 Effects of sampling time on leaf nutrients

It was decided to take leaf samples twice a year for a certain number of years in order to find the right sampling season for experimental plots. The months of May and December were chosen for the following reasons:

(a) In May, the cool season and about 3 months after fertilizer application, peak cropping is just over and the bush is under stress.

(b) In December, the warm season just before the January fertilizer application, the bush is cropping heavily and is again under stress.

Tables 3 and 4 respectively show the major nutrient levels in third and mature leaves, measured for all the experiments at the two chosen sampling times.

TABLE 3

MAJOR NUTRIENT LEVELS IN THIRD LEAF IN MAY AND DECEMBER

Sampling time

Nutrient / *Experiment*	*May*			*December*		
	N%	*P%*	*K%*	*N%*	*P%*	*K%*
IIIA ...	3.57	0.311	2.03	3.42	0.310	1.79
VC ...	3.48	0.301	1.88	3.58	0.305	1.74
XIA ...	3.44	0.324	1.93	3.40	0.316	1.89
XIB ...	3.16	0.286	1.83	3.13	0.265	1.68
XII ...	2.92	0.256	1.74	2.53	0.240	1.63

TABLE 4

MAJOR NUTRIENT LEVELS IN MATURE LEAF IN MAY AND DECEMBER

Sampling time

Nutrient / *Experiment*	*May*			*December*		
	N%	*P%*	*K%*	*N%*	*P%*	*K%*
IIIA ...	3.01	0.204	1.37	3.12	0.193	1.34
VC ...	3.16	0.213	1.37	3.10	0.192	1.40
XIA ...	3.12	0.221	1.41	3.16	0.207	1.48
XIB ...	2.96	0.193	1.31	2.93	0.187	1.51
XII ...	2.60	0.166	1.16	2.56	0.158	1.37

From table 3, it is found that the levels of all three major nutrients in the third leaf are higher in May than in December in all the experiments except in experiment VC where nitrogen and phosphorus show a reversal of the observed trend. This could be due to the fact that experiment VC received fertilizer application at a timing different from the other experiments. Table 4 shows that in the mature leaf no definite trend is clear, except that the phosphorus level is higher in May than in December. The situation concerning the micro elements investigated is illustrated in tables 5 and 6.

TABLE 5

MICRO NUTRIENT LEVELS IN THIRD LEAF IN MAY AND DECEMBER

Sampling time

Nutrient / *Experiment*	*May*				*December*			
	Ca%	*Mg%*	*Zn mg/kg*	*Cu mg/kg*	*Ca%*	*Mg%*	*Zn mg/kg*	*Cu mg/kg*
IIIA ...	0.38	0.24	23	13	0.30	0.17	22	11
VC ...	0.42	0.22	20	13	0.31	0.16	18	11
XIA ...	0.40	0.23	22	13	0.30	0.17	20	11
XIB ...	0.31	0.24	22	11	0.36	0.18	19	9
XII ...	0.19	0.22	19	10	0.21	0.21	20	9

TABLE 6

MICRO NUTRIENT LEVELS IN MATURE LEAF IN MAY AND DECEMBER

Nutrient / Experiment	Sampling time: May Ca%	May Mg%	May Zn mg/kg	May Cu mg/kg	December Ca%	December Mg%	December Zn mg/kg	December Cu mg/kg
IIIA ...	0.74	0.26	12	9	0.67	0.19	13	7
VC ...	0.73	0.22	10	9	0.65	0.17	11	8
XIA ...	0.73	0.24	12	9	0.66	0.17	10	9
XIB ...	0.67	0.27	12	8	0.54	0.19	12	8
XII ...	0.54	0.30	10	8	0.47	0.21	13	7

From table 5, it can be seen that third leaf elements calcium, magnesium, zinc and copper are all at higher levels in May than in December, although calcium in experiments XIB and XII and zinc in experiment XII depart from the general observation. Table 6 indicates that in the mature leaf calcium and magnesium are higher in concentration in May than in December. Zinc and copper are almost at the same levels.

It can therefore be said that, in general, the nutrients are present at higher levels in May than in December in the sampled leaves.

3.3 *Relation between yield of green leaf and leaf chemical composition*

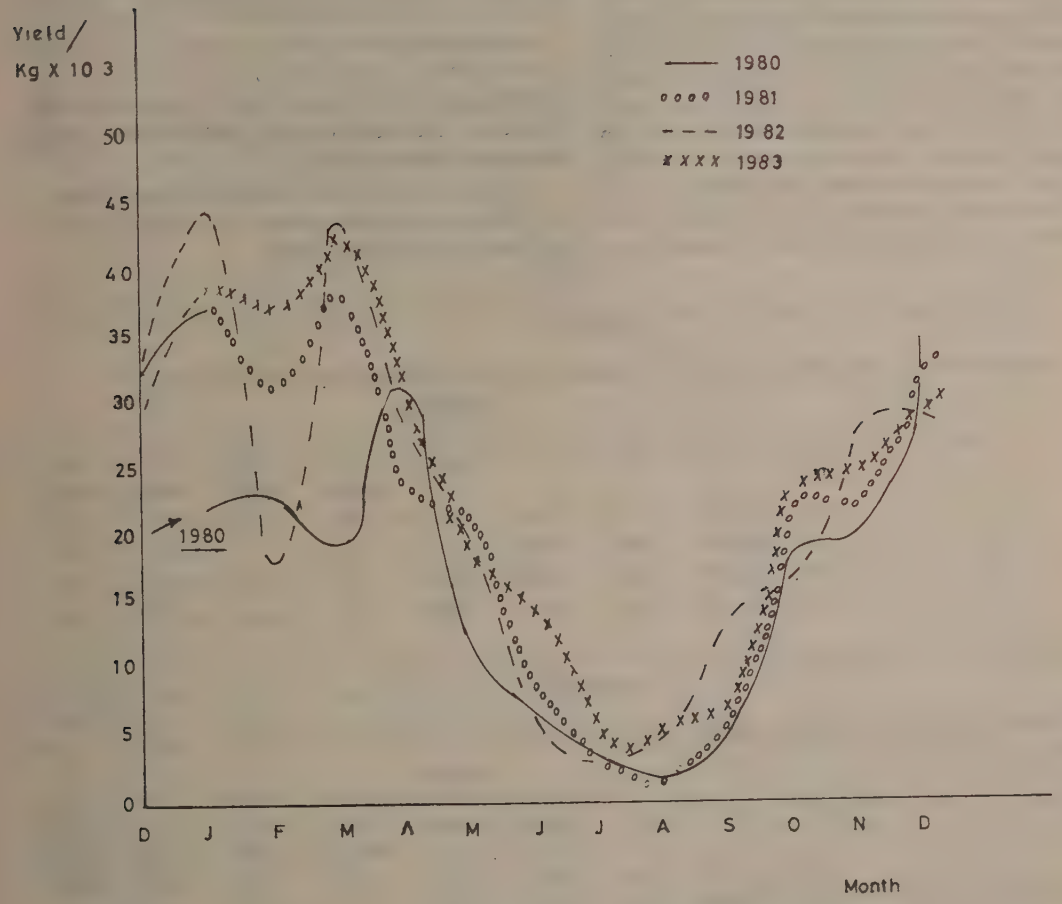
Table 7 shows the monthly yield of green leaf obtained at Wooton Station during the period 1980 to 1983. Fig. 1 is its graphical representation, where yield is taken to the nearest 1000 kilograms.

TABLE 7

YIELD OF GREEN LEAF (KILOGRAMS) AT WOOTON T.E.S 1980–1983

Year	Month: Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1980 ...	22427	23442	18728	31542	11502	6607	3621	1364	5238	19379	20197	32020
1981 ...	37591	30916	39333	23562	21735	8589	3250	2100	5016	23876	22576	32342
1982 ...	45334	18137	44231	28850	20988	5336	2919	4614	15000	17472	29091	28943
1983 ...	39042	37132	42938	31631	19889	15001	5326	5676	6555	24293	25049	29110

Fig 1 Monthly Variations of Yield of Green Leaf at Wooton 1980 TO 1983



It is evident from fig. 1 that peak cropping is not reached in December and the bush is not really under stress then. December is the period of increasing leaf production brought about by a rise in atmospheric temperature. Leaf production reaches a first peak in January but after fertilizer application the production goes down in February. This decrease in leaf production as a result of fertilizer application is characteristic of the tea bush and the effect has been observed in all tea growing countries (Woodford and Cooper, 1941). The bush, however, picks up very quickly, being boosted by the applied fertilizer, warm climate and adequate rainfall and produces another maximum crop in March/April. May has therefore been rightly postulated to be the time when the bush is under stress. Following a period of maximum metabolic activity, the bush now draws minerals heavily on its wood reserves and from the soil. This explains why leaf mineral content is higher in May than in December. For fertilizer response studies it would therefore be better to sample leaves in May, which confirms the idea put forward by Rosenquist (1978).

3.4 *The situation in the control plot from 1980 to 1983*

The control plot formed part of experiment IIIA. It received the basal dose of NPK fertilizer during the years 1980 to 1983.

Tables 8 and 9 show the mean yearly levels of the different nutrients analysed for in the third leaf and mature leaf respectively.

TABLE 8

MEAN YEARLY NUTRIENT LEVELS IN THIRD LEAF IN THE CONTROL PLOT, 1980–1983

	Nutrient								
Year	*N%*	*P%*	*K%*	*Ca%*	*Mg%*	*Zn mg/kg*	*Cu mg/kg*	*Fe mg/kg*	*Mn mg/kg*
1980	3.60	0.288	2.33	0.25	0.20	23	13	51	600
1981	3.63	0.308	2.00	0.28	0.21	29	11	65	767
1982	2.95	0.281	1.94	0.37	0.19	25	10	55	713
1983	2.65	0.280	2.28	0.48	0.20	22	12	70	861

TABLE 9

MEAN YEARLY NUTRIENT LEVELS IN MATURE LEAF IN THE CONTROL PLOT, 1980–1983

	Nutrient								
Year	*N%*	*P%*	*K%*	*Ca%*	*Mg%*	*Zn mg/kg*	*Cu mg/kg*	*Fe mg/kg*	*Mn mg/kg*
1980	2.90	0.200	1.65	0.51	0.19	13	10	73	1035
1981	2.71	0.186	1.43	0.72	0.24	17	10	84	1541
1982	2.59	0.151	1.50	0.47	0.22	15	8	47	1146
1983	2.83	0.173	1.32	0.85	0.17	9	6	91	1727

As can be seen from both tables, the NPK contents of both types of leaves have decreased by small amounts only and the decrease has not been the cause of any leaf starvation. Calcium has increased because of its immobility and magnesium has remained almost the same. Apart from a slight decrease in the copper level, the remaining minor nutrients have not suffered serious variations. The plants in the control plot have therefore not been under any severe stress under the basal dose fertilizer regime.

3.5. Elemental variations — an overall view

3.5.1. *Nitrogen*

Nitrogen is the element 'par excellence' which controls the growth of any plant, especially one like tea plant, where production of leaves is of prime importance. According to Eden (1976) 75% of the nitrogen in the average quality leaf for tea manfacture is in the form of proteins and aminoacids as the basic constituents of protoplasm. The remaining 25% forms part of the alkaloid caffeine. Included in the protoplasmic proteins are various enzymes which are important for the fermentation process during tea manufacture.

From table 10 it can be seen that third leaves at Wooton contain an average of 3.48% nitrogen. This compares favourably with the level that has been generally found in similar leaves in other tea growing areas. For example Tolhurst (1971) found in the third leaf in Tanzania, a level of 3.25% and Willson (1970) reported a content of 3.59% in similar leaf in Kenya. It is however, of interest to note that Tolhurst (1971) found that during hot rainy weather, third leaf nitrogen can rise to as much as 5.25%

TABLE 10

MEAN MAJOR NUTRIENT LEVELS IN THIRD AND MATURE LEAVES IN RELATION TO EXPERIMENTAL SITE

	Element					
	Nitrogen %		*Phosphorus %*		*Potassium %*	
leaf	*Third*	*Mature*	*Third*	*Mature*	*Third*	*Mature*
site						
Wooton ...	3.48	3.11	0.311	0.205	1.88	1.40
Verdun ...	3.15	2.95	0.276	0.190	1.76	1.41
Plaine Sophie ...	2.74	2.57	0.248	0.162	1.69	1.27

In N.E. India, under Assam conditions, Barua and Deb. (1960) have found that third leaf nitrogen varies from 4.78% to 5.23% at the Tocklai Experiment Station.

Leaf nitrogen at Plaine Sophie is definitely below the parvalues, whereas at Verdun, the level appears to settle down as an average of the levels found at the two other sites.

The decrease in leaf nitrogen from the third leaf to the mature leaf (Table 10) is in agreement with all observations made by many workers, that leaf percentage nitrogen decreases with age. This has been attributed to a gradual increase in non-nitrogenous matter (Barua and Deb. 1960).

3.5.2 *Phosporus*

Though phosphorus in the tissues is low, soil supplies are frequently sufficient, even in tropical soils where low phosphorus is widely recognized.

The measured level of 0.311% in the third leaf at Wooton (Table 10) is comparable to the values usually found in similar leaves in other countries. For instance, Lamb (1949b) reported a level of 0.32% found in Sri Lanka.

Third leaf phosphorus at Vedun and Plaine Sophie is below the generally accepted values.

An appreciable difference is noted between the phosphorus contents of third and mature leaves. This is an age effect, which has been observed and reported by Chenery (1955). As a result of some pot experiments carried out at Kew, in England, Chenery found that leaf one could contain as much as 0.405% phosphorus, whereas leaf twenty as little as 0.063% phosphorus.

It has generally been observed that nitrogen is about ten times phosphorus in well-balanced plant leaves. Table 11 below, gives a general idea of the proportions found in tea leaves under Mauritius conditions. Ratios in columns 2, 3, 4 are computed from values shown in table 10. Ratios in the last column are calculated from nitrogen and phosphorus values found by Ramanjooloo (1977) during an investigation of leaf major nutrients on a representative plot at Wooton.

TABLE 11

THE RATIO NITROGEN TO PHOSPHORUS

	Location			
	Leaf position		*Leaf position*	
	Wooton	*Verdun*	*Plaine Sophie*	*Wooton (Representative plot)*
First ...	N.S*	N.S	N.S	$\frac{4.96}{0.55}=9.02$
Second ...	N.S	N.S	N.S	$\frac{4.19}{0.45}=9.02$
Third ...	$\frac{3.48}{0.311}=11.19$	$\frac{3.15}{0.276}=11.41$	$\frac{2.74}{0.248}=11.05$	$\frac{3.51}{0.39}=9.00$
Mature ...	$\frac{3.11}{0.205}=15.17$	$\frac{2.95}{0.110}=15.53$	$\frac{2.57}{0.162}=15.86$	N.S

* N.S = not sampled

The ratios for the first three young leaves on the shoot are close to the accepted 10:1 value. But N/P ratio for mature leaves does not follow similar trend. Due to the steep loss in phosphorus as from the fully expanded leaf five, the N/P ratio in old leaf reaches a value 15:1. The rate of decrease of the percentage of nitrogen is therefore not so steep as that of phosphorus as the leaf ages on the bush.

3.5.3 *Potassium*

In concentration, potassium ranks highest among the mineral constituents and is one of the most important of the basic nutrients needed by the tea bush. The young leaves are the richest.

Eden (1976) has quoted De Haan and Schoorel who placed the absolute potassium deficiency levels below about 0.6% of dry matter. Where luxury consumption is operative leaf potassium percentage may rise to as much as 2.0. From the values of potassium levels shown in table 10, it is clear that problems relating to potassium excess or deficiency do not exist in all the tested plots.

3.5.4 *Calcium*

Next to potassium, calcium is the most abundant mineral in the tea leaf. The third leaf at Wooton and Verdun contains an average of 0.35%. Plaine Sophie leaves show an apparent lack of calcium (Table 12).

TABLE 12

MEAN MICRO NUTRIENT LEVELS IN THIRD AND MATURE LEAVES IN RELATION TO EXPERIMENTAL SITE

	Element							
	Calcium%		*Magnesium%*		*Zinc mg/kg*		*Copper mg/kg*	
	Leaf		*Leaf*		*Leaf*		*Leaf*	
Site	*Third*	*Mature*	*Third*	*Mature*	*Third*	*Mature*	*Third*	*Mature*
Wooton ...	0.35	0.70	0.20	0.21	21	11	12	9
Verdun ...	0.34	0.61	0.21	0.23	21	12	10	8
Plaine Sophie ...	0.20	0.51	0.22	0.26	20	12	10	8

Physiologically, calcium has the very important function of converting the poisonous leaf ethanedioic acid (Oxalic acid) into the relatively harmless calcium salt, which on account of its insolubility is not present in the tea extract.

Calcium is not a mobile element in the tea bush, as it is locked up in the plant cell as the crystalline insoluble ethanedioate. Consequently calcium concentration tends to go up as the leaf ages. At Wooton the mature leaf has been found to have accumulated an average of 0.70% of calcium. Chenery (1955) reported a value of 0.77% and was of the opinion that is was quite considerable.

3.5.5 *Magnesium*

This element is an integral part of the chlorophyll molecule of the leaf. It is therefore directly associated with all photosynthetic activities for the energy building-up of the plant. A deficiency of magnesium would cause depletion of the carbohydrate reserve of the plant which would seriously impede the nitrogen uptake thereby producing numerous biological complications.

All the sampled leaves show a remarkable constant magnesium level, slightly above 0.20% unaffected by the season, fertilizer regime, soil type and age of the leaf (Table 12).

Chenery and Schoenmaekers (1959) have shown that magnesium deficient leaves contain less than 0.2% of the element and have a K/Mg ratio above 10. This is not the case with the sampled leaves at all the three experimental sites. Leaf magnesium percentage is above 0.2 and as table 13 indicates, the K/Mg ratios are below 10.

TABLE 13

LEAF K/Mg RATIOS AT THE DIFFERENT EXPERIMENTAL SITES

Leaf	*Site*		
	Wooton	*Verdun*	*Plaine Sophie*
Third ...	$\frac{1.88}{0.20}=9.40$	$\frac{1.76}{0.21}=8.38$	$\frac{1.69}{0.22}=7.68$
Mature ...	$\frac{1.40}{0.21}=6.67$	$\frac{1.41}{0.23}=6.13$	$\frac{1.27}{0.26}=4.88$

The decreasing K content of old leaves explains the rather low K/Mg ratios for the mature leaves.

3.5.6 *Zinc*

Like so many of the other plant trace elements, zinc probably activates a number of the plant enzyme systems. Furthermore, Barpujari and Dey (1982) have shown that zinc helps in root formation and can therefore induce greater root poliferation in young tea. Also, Venkataram (1979) in South India, has reported that tea cuttings which were previously treated with zinc solution have shown better root development than untreated ones and it is recommended practice there, to spray mother bushes with 1% zinc sulphate solution about a week prior to taking cuttings. From table 12 it can be seen that similar leaves from all the experimental sites have shown similar constant zinc levels. Young third leaves maintained a concentration of 21 mg/kg and the mature leaves a concentration of 12 mg/kg. The zinc level in the third leaf at least, is within safe limits because Barjapuri and Dey (1982) have pointed out that the minimum concentration in young leaf below which growth is likely to be effected is 17 mg/kg. Furthermore. visual zinc deficiency syndromes as described by Tolhurst (1973) and quoted by Eden (1976) have not been met with in Mauritius.

3.5.7 *Copper*

Copper is one of the elements essential to the normal functioning of life processes. Its presence in the cell respiration of plants is well known.

In the tea plant, it plays an additional vital role. Its presence in the prosthetic group of the oxidase enzyme is essential for the exidation of tea polyphenol during "fermentation", which is the most important chemical process occuring in tea manufacture. One-third of the total leaf copper exists as enzymic copper and Sreerangachar (1943) has shown that the activity of the enzyme has a direct relationship to its copper content. However, although it is known that teas deficient in enzymic copper do not ferment properly, Eden (1976) thinks that is it not possible to dogmatize on the causes of slow or imperfect fermentation in regions where leaf copper content is low, because it may not be unlikely that more than one enzyme is involved in the process.

Copper in the shoot varies in the order: bud > leaves > stalks. Ramaswamy (1960) has reported a level of 33 mg/kg in the bud, 25 mg/kg in the first leaf, 26 mg/kg in the second leaf and 19 mg/kg in the stalk. According to the author, the copper content of the tea flush in Sri Lanka, varies from 16 to 30 mg/kg.

Although comparable leaves are not considered, it can be deduced from table 12 that the copper content of the Mauritian tea leaves is rather low. However, Wooton leaves seem to be comparatively better.

3.5.8 *Iron*

Table 14, below shows to what extent the iron content in tea leaves can be variable.

TABLE 14

RANGE OF IRON AND MANGANESE LEVELS IN THIRD AND MATURE LEAVES IN RELATION TO EXPERIMENTAL SITE

	Element			
	Iron mg/kg		*Manganese mg/kg*	
	Leaf			
Site	*Third*	*Mature*	*Third*	*Mature*
Wooton	28 — 248	30 — 355	201 — 2714	349 — 4000
Verdun	27 — 470	31 — 290	83 — 2443	119 — 2716
Plaine Sophie ...	21 — 178	36 — 210	216 — 909	546 — 2947

Values as low as 21 mg/kg and as high as 355 mg/kg have been met with. Leaf iron does not seem to bear any relationship either to the position on the flush or to the age of the leaf on the bush. Even within a given experimental block leaf samples show wide variations of iron content, which could be due to the non-uniform distribution of iron sesquioxides in tropical soils as well as to the limited mobility of insoluble iron phosphate in the highly acid tea soils. Iron is not very mobile in the leaf as well, and this accounts for the uneven distribution of the element in the tea bush.

Underwood (1956) has mentioned that in the plant, iron functions as a constituent of a number of oxidative enzymes in a manner similar to copper and is intimately related to the latter in its metabolism. Both iron and copper are constituent elements of plant cytochromes. But the mechanism of iron absorption is very peculiar and it has a complex intermediary metabolism in the plant cell.

3.5.9. *Manganese*

Manganese and iron are very closely related in their electronic constitution and configuration. Their chemistry is therefore alike and they have similar behaviour in the environment. They even occur together in the soil and are related in plants.

It is therefore not surprisingg that in tea plant, manganese is as variable as iron is. This is illustrated in Table 14. Levels as low as 83 mg/kg in the third leaves at Verdun and as high as 4000 mg/kg in the mature leaves at Wooton have been detected.

Most plants are virtually dead by the time they have accumulated about 1000 mg/kg manganese in their tissues. But the tea plant is exceptional. It can take massive levels of manganese without any apparent harm. Sivasubramaniam (1970) has, however, reported that high manganese uptake has depressing effects on growth.

Chenery (1955) has reported values as high as 9150 mg/kg in mature leaves in Malawi under field conditions. In the pot experiments at Kew, the same author found that tea seedlings which had grown to about 20 cm high could accumulate an extraordinary 31000 mg/kg of manganese in their third leaves. The pot, it must be underlined, had been treated with a 10000 mg/dm^3 solution of manganese (II) ions. Such luxury consumption and storage of manganese within the tea plant has been reported by many other researchers in various tea growing areas. Unlike aluminium accumulation, which increases indefinitely with age of leaf in the tea plant, manganese accumulation reaches a peak as the leaf ages. Then a reverse translocation takes place as the bush prepares to shed the leaf. Dropping leaves have been found to contain less manganese than mature leaves.

Manganese is believed to have functions connected with germination and early development of the plant as well as with the photosynthetic process and chlorophyll formation. But Prasad and Dey (1970) have stated that no satisfactory explanation has yet been put forward about the metabolic function of manganese within the tea plant. The same authors have, however, confirmed that manganese is helpful in the uptake of phosphorus by the tea plant. Chenery (1955) was the first to observe this fact during his pot experiments at Kew, who nonetheless had cautioned that high phosphorus uptake coupled with high manganese uptake could induce manganese toxicity and cause leaf chlorosis due to an upset of the balance with iron.

CONCLUSIONS

(i) Young tea planted at Verdun on humic ferruginous latosol has slightly higher levels of nitrogen, phosphorus, potassium and calcium than young tea planted at Plaine Sophie on similar soil. This is because the Verdun soil has slightly better response to fertilizer application than the Plaine Sophie soil, as shown by the data in table 15 below.

TABLE 15

SOIL NPK LEVELS IN RESPONSE TO FERTILIZER TREATMENTS AT DIFFERENT EXPERIMENTAL SITES*

	Site		
Fertilizer	*Wooton*	*Verdun*	*Plaine Sophie*
300 kg N/ha/yr ...	0.35%N	0.25% N	0.19% N
90 kg P_2O_5/ha/yr ...	44 mg P/kg	12mg P/kg	11 mg P/kg
30 kg K_2O/ha/yr ...	0.33 me K/100g	N.A. †	0.14 me K/100g
60 kg K_2O/ha/yr ...	0.38 me K/100g	0.18 me K/100g	N.A.

*Courtesy Scientific Officer N. Coonjan, Agric. Chem. Division
†N.A. means treatment not applied at this site
‡N. means total nitrogen, P. available phosphorus and K exchangeable potassium

(ii) Mature tea at Wooton on latosolic brown forest soil has higher levels of nitrogen, phosphorus, potassium and calcium than tea at Verdun and Plaine Sophie. This is because the younger soil at Wooton, as evidenced by the above table, has a much better response to fertilizer treatments than the soil at the two other sites.

(iii) Leaf Magnesium, zinc and copper show almost constant levels irrespective of experimental sites.

(iv) No comparison is possible for iron and manganese as their levels show very wide variations in the leaves.

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Reduit,

11 March, 1986

REFERENCES

Barua, D. N. and Deb, S. B. (1960). Variation in the nitrogen content of tea leaves. J. Sci. Fd. Agric. Vol. 11, 366.

Barpujari, N. and Dey, S. K. (1982). Zinc requirement of tea in N. E. India. Two and a bud. Vol. 29 (2), 40.

Chenery, E. M. (1955). A preliminary study of aluminium and the tea bush. Plant and soil. Vol. 6 (2), 174.

Chenery, E. M. and Schoenmaekers, J. (1959). Magnesium deficiency in East African tea. E. Afr. Agric. J. Vol. 25, 25.

Eden, T. (1976). Tea. 3rd ed. Tropical Agriculture series. Longman London.

Lamb, J. (1949b). Analysis of tea leaf grown at different elevations. TRIC Ann. Rep. p. 27.

Prasad, A. and Dey, S. K. (1979). Influence of phosphate on manganese uptake by tea. Two and a bud. Vol. 26 (1), 7.

Ramanjooloo N. N. (1977). Ann Rep. Min. of Agric. Mauritius p. 115.

Ramaswamy, M. S. (1960). Copper in Ceylon Teas. Tea Quart. Vol. 31 (2) 76 — 80.

Rosenquist, E. A. (1978). Harrisons Fleming report on the Mauritius tea industry. p. 3.

Sivasubramaniam, S. (1970). Ph. D. Thesis. London University.

Sreerangachar, H. B. (1943). The purification of tea oxidase enzyme in relation to copper content. Biochem. J. Vol. 37, 661.

Tolhurst, J. A. H. (1971). Proc. Symp. TRIEA March 1971.

Tolhurst, J. A. H. (1973). Zinc deficiency in tea. TRIEA. Pamphlet 21/73.

Underwood, E. J. (1956). Trace elements in human and animal nutrition. Academic Press Inc. N. York.

Venkataram, C. S. (1979). Ann Rep. UPASI. P. 9.

Willson, K. C. (1970). Use of principal component analysis on data from chemical analysis of tea leaves. Expt. Agric. Vol. 6. 319 — 325.

Woodford and Copper (1941). A factorial experiment on the manuring of young tea. Emp. J. Exp. Agric. Vol. 9. 12.

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The aim of this bulletin in essentially to disseminate technical information generated by research undertaken by the Technical Staff of the Agricultural Services of the Ministry of Agriculture, Fisheries and Natural Resources. This publication is intended to cover all sectors in Agriculture and to reach a wide reading public within the Farming Community.

Contributions are welcome from all research workers within the Ministry and allied Parastatal Bodies. Further details are available from the Secretary c/o Land Use and Projects Division, Réduit, to whom contributions should be addressed.

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